UNIVERSITI PUTRA MALAYSIA

ANALYSIS AND FABRICATION OF FUSED FIBER OPTIC COUPLERS FOR COMMUNICATION SYSTEMS

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By

AHMAD ZAKI BIN HAJI SHAARI

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirement for the Degree of Master of Science

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DEDICATION

In the name of Allah, Most Gracious and Most Merciful

For the sake of seeking knowledge

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

ANALYSIS AND FABRICATION OF FUSED FIBER OPTIC COUPLERS FOR COMMUNICATION SYSTEMS

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Faculty: **Engineering**

Optical couplers such as fused optical fiber coupler are widely used in the network communication systems as either splitters or combiners. There are not much of theories available to describe the core and cladding interaction model inside fused coupler's region. In this study, suitable Models for analysis of core to cladding guidance interaction using BPM_CAD simulation are created. While core guidance occurs in between core ratios 1 to 0.65, cladding guidance does support propagation at certain core ratio lower than 0.65 with slightly different results between various Models. The Models are also able to generate low excess losses in both the simulated core guidance and cladding guidance.

Excess loss in real fused couplers depends on their elongations, which can be controlled through certain set-up parameters such as torch head positions and motor speed. The effects of changing hydrogen flowrate and

torch head positions do not have direct relationship with the insertion loss of WDM coupler, hence scientifically, the conclusion of fusion temperature effect on coupling cannot be made. Some design parameters are found out to confirm quite well with the parameters found from fabrication. This has been demonstrated through theoretical pulling signatures for various fused couplers.

Besides examining 1 x 2 fused couplers, the study on triangular shape arrangement of 1 x 3 monolithic star couplers do indicate that equal couplings in all output ports are possible if correct Intertwined Method of twisting fibers is used. The same technology used in fabricating fused coupler, is used to fabricate lattice filter, which has channel spacing 2.84 nm or 178 GHz. Generally, all the studies are carried out at most levels including theory, simulation and experiment. These findings or data are analyzed to show the relationship between them and they are also discussed in details in this thesis.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

ANALISA DAN FABRIKASI PENGGANDING GENTIAN OPTIK TERLAKUR UNTUK SISTEM KOMUNIKASI

Oleh

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April 2006

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Pengganding optik, seperti pengganding gentian optik terlakur, telah digunakan secara meluas didalam sistem komunikasi rangkaian sebagai pembahagi atau penggabung. Tidak terdapat banyak kajian teori dilakukan mengenai model interaksi pergerakan terurus teras ke *cladding* didalam pengganding terlakur. Dalam kajian ini, model-model tertentu telah dicipta untuk analisa interaksi pergerakan terurus teras ke *cladding* dengan mengunakan perisian simulasi BPM_CAD. Didapati, pergerakan terurus *cladding* memang berlaku pada model tertentu jika nisbah diameter teras kurang dari 0.65 manakala pergerakan terurus teras berlaku pada nisbah diameter teras diantara 1 dan 0.65. Walaupun begitu, terdapat sedikit ketidaksamaan diantara model-model tersebut. Model-model juga berjaya menghasilkan lesapan lebihan yang kecil bagi kedua-dua simulasi pergerakan terurus teras dan *cladding.*

Lesapan lebihan didalam pengganding terlakur bergantung kepada panjang pengganding tersebut tetapi didapati kawalan keatas lesapan itu bergantung kepada parameter-parameter seting tertentu seperti posisi Kepala Penunu dan kelajuan motor. Kadar perubahan aliran hidrogen dan posisi Kepala Penunu tidak menunjukkan perhubungan langsung dengan lesapan sisip bagi pengganding terlakur *WDM.* Secara saintifiknya, kesimpulan bahawa suhu pelakuran mempengaruhi pengandingan tidak dapat dibuat. Parameter-parameter reka bentuk tertentu didapati ada perhubungan yang baik dengan parameter-parameter yang didapati dari fabrikasi. Ini telah ditunjukkan didalam graf teori *pulling signatures* bagi perbagai pengganding terlakur.

Selain kajian keatas pengganding terlakur 1 x 2, kajian juga dilakukan keatas pengganding terlakur 1 x 3 berbentuk susunan tigasegi yang boleh mengeluarkan kuasa penggandingan sama diantara ketiga-tiga arah keluaran *ports* jika Cara *Intertwined* yang betul diguna pakai bila melilitkan gentian-gentian optik berkenaan. Kajian keatas *Lattice Filter* juga dibuat dengan menggunakan teknologi yang sama untuk pembuatan pengganding terlakur tersebut. Didapati *Lattice Filter* berkenaan mempunyai ruangan saluran sebanyak 2.84 *nm.* Secara amnya, semua kajian yang dijalankan melibatkan teori, simulasi dan uji kaji. Kesemua penemuan atau data dianalisa untuk mencari perhubungan diantara kesemua parameter-parameter berkenaan dan dibincang secara menyeluruh didalam tesis ini.

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I certify that an Examination Committee has met on 20 April 2006 to conduct the final examination of Ahmad Zaki Bin Haji Shaari on his Master of Science thesis entitled "Analysis and Fabrication of Fused Fiber Optic Couplers for Communication Systems" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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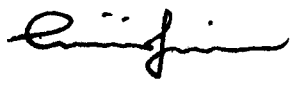

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DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations, which have been duly acknowledged. I also declare that it has not previously or concurrently submitted for any other degree at UPM or other institutions

AHMAD ZAKI BIN HAJI SHAARI

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LIST OF ABBREVIATIONS

BPM	Beam Propagation Method
CAD	Computer Aided Design
CH	Photodetector
CMT	Coupled Mode Theory
CPU	Central Processing Unit
CR	Coupling Ratio
CW	Coupler Workstation
CWDM	Coarse Wavelength Division Multiplexing
DWDM	Dense Wavelength Division Multiplexing
EL	Excess Loss
FBT	Fused Biconical Taper
FTP	Flame Torch Position
FTTH	Fiber to the Home
IL	Insertion Loss
ITU	International Telecomunication Union
LM	Lower Modes
MFD	Mode Field Diameter
MZI	Mach Zehnder Inteferometer
OLT	Optical Line Terminal
ONU	Optical Network Unit
OSA	Optical Spectrum Analyzer
PDL	Polarization Dependent Loss

PL	Pull Length
PON	Passive Optical Network
SMF	Single Mode Fiber
WDM	Wavelength Division Multiplexing
WSF	Wavelength Selective Fused